XIV. *A comparison of the changes of magnetic intensity throughout the day in the dipping and horizontal needles, at Treurenburgh Bay in Spitsbergen. By* Captain Henry Foster, *R.N. F.R.S.*

Read May 8, 1828.

THE few observations I had an opportunity of making at Port Bowen in 1825, on the diurnal changes of intensity shown by the dipping and horizontal needles, first suggested the idea of a daily rotatory motion of the general polarizing axis of the earth, as the cause, not only of the diurnal changes of intensity, but also of the diurnal oscillations of the horizontal needle throughout the world. And the circumstance, of the times of the maximum and minimum effect of these phænomena, occurring generally when the sun bore north, south, east, and west by compass, indicated his agency in producing this motion of the pole.

The entire confirmation of an hypothesis so important in the theory of terrestrial magnetism, requires the evidence of varied and extensive observation; and as my professional pursuits have recently led me to revisit those regions best calculated for the experiments, I have thought a continuation of them under favourable circumstances, might prove an useful auxiliary to those already honoured with a place in the Philosophical Transactions for 1826.

The observations which I have now the honour to present to the Royal Society, were performed in a manner somewhat different from those alluded to at Port Bowen, which were made with one needle only, first as a dipping needle, and then suspended horizontally. Whereas in this case, two needles were employed, each in its respective capacity; an arrangement far more convenient in practice, and equally satisfactory as to the object I had in view; which was simply to ascertain, whether or not a corresponding change of intensity exhibited itself in both needles, whether each was differently affected thereby, or whether such change belonged to the horizontal needle alone.

The expression for the intensity of the dipping needle, is $I = 2A\sqrt{\frac{1}{4 - 3\sin^2\delta}}$, and for the horizontal needle, $I = 2A\sqrt{\frac{1}{3 + \sec.^2\delta}}$, δ denoting the dip, A a general co-efficient. Consequently, if the change took place in the co-efficient A only, that is in the general magnetic intensity, both needles would be proportionally affected, and in the same manner; but if the change were in the dip only, then the two needles would be differently affected; the dipping needle, as $\sqrt{\frac{1}{4 - 3\sin^2\delta}}$, and the horizontal needle, as $\sqrt{\frac{1}{3 + \sec^2\delta}}$, so that one would increase in intensity and attain its maximum, while the other would decrease and attain its minimum, and *vice versa.*

If both δ and A be variable, the relation between the simultaneous intensities of the two needles would remain the same as if δ only changed, because it is common to both needles; but the comparison of the same needles, at different times of the day, would be considerably modified by such a change in the value of A, and which would appear to be the case both from the present observations and those at Port Bowen. For example, if A was a maximum when the dip was the greatest, and consequently when the horizontal intensity, from considerations of dip only, was the least, the one effect would in some measure counteract the other on the horizontal needle; whereas the dipping needle would have its intensity increased from both these causes operating at the same time, and contrariwise if at the moment of least dip A should be at its minimum. It is, however, by no means my intention at present to enter upon this intricate inquiry; my object being to examine whether the simultaneous changes in the intensities of the two needles are of a character to indicate a change of dip as one at least of the causes, or whether the dip remains constant, and the change is due to that of intensity alone. As far as this question is concerned, the results are certainly satisfactory; for on comparing the intensities of the two needles given in Table II. it will be found that the intensity of one needle was generally the greatest when the other was the least, and the contrary. That a change actually takes place in the general intensity of the earth's magnetism, is as an hypothesis very reasonable; still, however, it is but an hypothesis, and as such I shall not insist upon it in this place, notwithstanding the circumstantial evidence furnished by these observations, but leave

it for more extended experiments to decide, and proceed at once to a detail of those observations from which the former deduction is made.

With respect to the instruments, they differed so little from those employed at Port Bowen, which have already been described, that it is unnecessary to say more than that the dipping needle was one belonging to the Board of Longitude, and made by Dollond; the needle used was in form a parallelopipedon, 6 inches long, 0.4 broad, and 0.05 thick, and that its magnetism was not interfered with while it was in my possession. The same may be observed of the horizontal needle, which was one of the same form and weight as the above.

The experiments were commenced upon the 30th of July, and continued to the 9th of August by myself only; and they were so arranged, that in the course of two days an observation was made every hour of the twenty-four, but part of them in one day, and part of them in the other, as shown in the Table.

Previous to the commencement of the observations, the silk thread (eleven inches long) which was employed for suspending the horizontal needle, was divested as far as could be of torsion, by suspending a brass needle of like form and of equal weight with the one above described; it was then replaced by the magnetized needle itself, the centre of which was brought directly over the centre of a graduated circle, by means of foot-screws attached to a board on which the apparatus stood. The needle being thus freely suspended, it was drawn out of the magnetic meridian somewhat more than 40 degrees, by a contrivance for that purpose; but its oscillations were not noticed until the arc had decreased to 40 degrees, when the observations were commenced on the times of performing ten vibrations successively, until two hundred were completed; the terminal arc and temperature of the instrument were then registered, and in this manner all the results given in the following Table were obtained.

The vibrations on the dipping needle were taken as follows: viz. one hundred with the face of the instrument East, previous to those on the horizontal needle as above described; and another hundred after the latter, with the face West; so that the mean time of observation for both needles was nearly the same, as will be seen by referring to Table I., relative to which, however, it should be observed, that although two hundred vibrations were taken by each needle, the time of performing one hundred only is recorded in the Table, as also the mean arcs of vibration.

Table I.

Containing the Observations on the Diurnal Changes of Intensity in the Dipping and Horizontal Needles at Treurenburgh Bay in Spitsbergen, in the Months of July and August 1827.

Dates.	Dipping Needle.				Horizontal Needle.			
	Hour.	Time of performing 100 Vib^{ns}.	Mean Arc.	Temp. Fahr.	Hour.	Time of performing 100 Vib^{ns}.	Mean Arc.	Temp. Fahr.
	h m	s	°	°	h m	s	°	°
July 30, A.M.	2 4	291.6	23.7	35	1 56	619.0	26.2	34½
	3 4	291.3	24	34½	2 56	620.0	24	34½
	3 58	291.2	23.8	34	3 50	620.9	23.7	35
	4 57	291.4	23.8	34	4 48	619.0	24.5	34
	6 1	292.1	23.5	35½	5 52	618.7	25	35
	7 0	291.9	23.2	35½	6 56	619.4	26	36
	7 47	292.2	22.8	36	7 46	619.4	26	35
	5 35	291.2	21.3	36½	5 36	613.6	25.5	36½
P.M.	6 3	291.2	21.2	35¾	6 22	616.6	25	36½
	8 14	291.9	22.2	35¼	8 19	615.6	25	36½
	8 56	291.7	22.2	35½	9 00	615.8	26	36½
	9 38	291.6	21.7	36	9 39	615.0	26	36
	10 26	291.6	21.7	36	10 37	615.1	25	36
	11 16	291.4	21.3	35½	11 25	621.1	26	36
	12 02	291.8	21.3	35	12 00	620.4	25	37
July 31, A.M.	9 17	292.2	21.7	40.2	9 23	618.6	25½	41½
	10 18	291.8	21.2	41.2	10 23	616.1	25¾	43
	11 20	292.4	22	41	11 25	612.5	25¾	41
P.M.	0 18	292.6	22.2	40½	0 22	610.0	26	42
	0 57	292.6	22	40	0 54	611.0	25½	42
	1 56	292.8	22.3	40	1 54	613.2	26	42
	2 56	293.0	22.5	39¼	2 54	619.1	26	40½
	3 52	292.5	22.2	39½	3 51	622.0	26	40
Aug. 1, A.M.	0 55	291.7	22.2	38	0 50	619.8	26	39
	1 55	292.0	22.1	38	1 55	618.6	25½	39
	2 54	291.6	21.9	38½	2 50	617.7	26	39
	3 52	291.6	22.2	39	3 51	618.3	25½	40
	4 53	292.3	22.3	39½	4 50	619.5	25½	40½
	5 50	292.4	22.1	40	5 47	618.9	25½	41
	6 57	292.3	22.2	41½	6 54	619.5	26	42
	7 41	292.4	21.8	41¾	7 42	619.9	25½	43
P.M.	5 36	292.9	22	48½	5 37	617.0	25½	50½
	6 57	292.8	22½	47¾	6 56	616.8	25½	46½
	7 57	292.6	22½	47½	7 58	617.4	25½	50
	9 1	292.6	22.3	47¼	8 56	617.9	26	52
	9 55	292.3	22.2	44	9 50	617.1	25½	45
	10 46	292.3	22.3	42½	10 47	617.7	25½	44
	11 52	292.7	20.7	41½	11 48	617.5	25½	43

Table I. (Continued).

Dates.	Dipping Needle.				Horizontal Needle.			
	Hour.	Time of performing 100 Vib^{ns}.	Mean Arc.	Temp. Fahr.	Hour.	Time of performing 100 Vib^{ns}.	Mean Arc.	Temp. Fahr.
	h m	s	°	°	h m	s	°	°
Aug. 2, A.M.	9 41	293.7	22.3	62.2	9 42	620.2	$25\frac{1}{2}$	64
	10 41	293.4	22.1	59.2	10 41	621.2	$25\frac{1}{2}$	$59\frac{1}{2}$
	11 39	293.5	22.1	58.2	11 41	619.0	$25\frac{1}{2}$	59
P.M.	0 50	293.8	22.2	$57\frac{1}{2}$	0 48	616.6	26	58
	1 53	293.3	21.9	$56\frac{3}{4}$	1 48	618.8	$25\frac{1}{2}$	56
	2 49	293.7	21.7	53.7	2 46	617.8	$25\frac{1}{2}$	$55\frac{1}{2}$
	3 37	293.6	21.1	53	3 40	619.0	$25\frac{1}{2}$	53
Aug. 3, A.M.	0 44	291.7	21.6	47	0 45	619.8	25	52
	1 46	292.2	21.5	47	1 47	618.8	25	$51\frac{1}{2}$
	2 45	292.0	21.3	$48\frac{1}{4}$	2 46	619.9	25	52
	3 41	291.7	21.5	50	3 43	619.7	25	55
	4 42	292.2	21.8	51	4 45	616.9	25	57
	5 45	293.0	22.1	$52\frac{3}{4}$	5 45	617.7	25	57
	6 43	293.4	22.1	$54\frac{1}{2}$	6 44	625.4	25	59
	7 46	293.4	21.9	$56\frac{1}{4}$	7 49	620.0	25	61
P.M.	6 41	293.7	22.7	$57\frac{1}{4}$	6 42	620.2	25	58
	8 2	293.6	22.7	53	8	619.7	25	54
	8 44	293.1	22.5	$51\frac{1}{2}$	8 46	619.8	25	52
	9 46	293.4	22.5	$49\frac{1}{4}$	9 47	621.1	$25\frac{1}{2}$	51
	10 46	293.1	22.2	$49\frac{1}{4}$	10 48	618.2	25	51
	11 41	292.2	22.1	49	11 43	617.3	25	53
Aug. 4, A.M.	9 12	293.7	22.3	$56\frac{1}{2}$	9 16	620.2	26	61
	9 57	293.9	22.7	$59\frac{1}{2}$	9 55	618.5	$25\frac{1}{2}$	63
	10 44	293.3	22.5	60	10 45	619.2	26	63
	11 37	292.6	22.1	$59\frac{1}{2}$	11 39	619.5	26	62
P.M.	0 40	292.8	22	60	0 41	619.2	26	63
	1 59	292.8	21.7	$62\frac{1}{2}$	1 55	619.0	$25\frac{1}{2}$	63
	2 42	293.6	22	$61\frac{3}{4}$	2 44	619.0	$25\frac{1}{2}$	64
	3 36	293.8	22.1	$63\frac{1}{2}$	3 38	618.4	$25\frac{1}{2}$	65
Aug. 5, A.M.	1 00	291.9	22	51	0 57	620.0	23	52
	1 43	291.5	22	51	1 44	620.8	25	$52\frac{1}{2}$
	2 45	291.9	22.1	51	2 47	619.5	$24\frac{1}{2}$	52
	3 41	291.5	21.7	50	3 42	618.5	24	51
	4 44	292.1	22.5	50	4 45	620.2	24	51
	5 41	291.4	21.8	$47\frac{1}{2}$	5 43	618.4	$23\frac{1}{2}$	$49\frac{1}{2}$
	6 43	291.8	22.1	49	6 45	616.4	24	51
	7 35	292.5	22.3	53	7 36	621.1	24	$52\frac{1}{2}$
P.M.	5 44	293.6	22.2	$49\frac{3}{4}$	5 46	619.2	26	$49\frac{1}{2}$
	6 35	293.1	22.7	$49\frac{1}{2}$	6 36	617.7	25	50
	8 1	291.6	22.4	47	7 57	620.7	25.5	$47\frac{1}{2}$
	8 46	292.1	22.2	$47\frac{1}{4}$	8 45	619.6	25.5	48
	9 45	291.8	22	47	9 46	619.6	26.5	$46\frac{1}{2}$
	10 46	292.5	22.3	47	10 47	618.3	25.5	$47\frac{1}{2}$
	11 43	292.0	22.2	$46\frac{1}{2}$	11 47	618.1	25	47

Table I. (Continued.)

Dates.	Dipping Needle.				Horizontal Needle.			
	Hour.	Time of performing 100 Vib^{ns}.	Mean Arc.	Temp. Fahr.	Hour.	Time of performing 100 Vib^{ns}.	Mean Arc.	Temp. Fahr.
	h m	s	°	°	h m	s	°	°
Aug. 6, A.M.	9 20	293.0	23.3	53¼	9 26	616.6	26	54
	10 00	292.7	23.3	54½	9 57	615.3	25½	54½
	10 42	292.4	23	55¼	10 44	614.0	26	55
	11 41	293.2	22.6	54¼	11 43	613.2	25.5	50
P.M.	0 51	292.6	22.4	56¼	0 49	614.7	25.5	57
	1 40	293.0	22.9	55	1 41	615.3	26	56
	2 51	292.9	23	55¾	2 49	616.8	26	58
	3 37	293.2	23.5	58¾	3 38	615.3	25.5	57
Aug. 7, A.M.	0 46	292.7	22.6	47	0 47	618.9	24.5	49
	1 42	291.8	22	48½	1 43	620.3	25	51
	2 44	292.5	22.5	45¼	2 47	619.6	25	46½
	3 38	292.1	22.9	45	3 38	620.9	25	46
	4 41	292.2	23	44½	4 42	620.0	25	45
	5 36	292.2	23	46	5 38	620.1	25.5	45
	6 41	292.1	23	43½	6 42	620.3	25.5	45
	7 38	292.7	23.2	42½	7 39	620.2	25.5	44
P.M.	5 37	292.1	23.6	41½	5 38	619.1	25.5	43
	6 42	292.1	23.5	40½	6 44	616.7	25.5	42½
	8 13	291.8	23.7	41	8 18	618.0	25.5	41½
	9 00	292.7	23.5	41¼	8 57	618.0	25.5	41½
	9 42	292.1	23.6	40½	9 43	618.1	25.5	41
	10 41	292.0	23.5	40	10 43	617.7	26	41
	11 44	291.2	23.5	40½	11 45	623.1	25.5	40½
Aug. 8, A.M.	9 18	291.6	23.5	47½	9 23	618.2	25.5	49
	10 6	292.6	23.4	51	10 14	619.9	26	53
	10 56	292.7	23.2	55¼	10 56	618.5	26	56
	11 39	293.1	23.1	56	11 40	618.0	26	57
P.M.	0 38	293.5	23.1	57¾	0 39	617.8	26	58½
	1 41	293.7	23.6	59	1 43	617.6	25.5	59
	2 39	293.8	23.3	58	2 41	622.1	25.5	60
	3 36	293.3	23.5	58¾	3 38	619.9	26	60
Aug. 9, A.M.	0 58	291.6	23.1	50	0 55	624.0	25	53½
	1 44	291.7	23.2	49½	1 45	622.5	25	52½
	2 37	291.6	23.5	50	2 39	623.2	25	53
	3 38	292.0	22.5	50½	3 38	625.3	25	54
	4 40	292.2	22.7	50	4 41	623.1	24.5	55
	5 55	292.1	22.3	52¾	5 53	622.1	21	54
	6 40	291.6	21.8	54	6 39	621.7	22.5	60
	7 35	293.3	22.3	57	7 36	623.0	25.5	61
P.M.	5 40	293.0	23.1	58	5 41	621.6	25.5	58
	6 40	293.3	23	58¾	6 42	622.6	26	58
	8 17	293.0	23.2	56	8 12	621.9	25.5	56½
	8 52	292.7	23.2	54½	8 50	621.5	25.5	55½
	9 42	292.3	22.9	53½	9 43	621.8	25	55
	10 41	291.9	22.7	54	10 42	619.8	25.5	54
	11 41	292.2	22.8	50¾	11 43	619.5	25	53

In order to bring more clearly into view the results of the foregoing observations, the following Table has been formed, by adding together all the *times* each needle took to perform one hundred oscillations at the respective hours of observation on the several days, and converting these times into proportional intensities. In the third and sixth columns are inserted the numbers expressive of intensities, which have been obtained, by squaring the reciprocal of the times, and multiplying those squares by 100,000, to render them all integral.

Table II.

Dipping Needle.			Horizontal Needle.		
Hour.	Time in seconds of performing 100 oscillations.	Proportional Intensity.	Hour.	Time in seconds of performing 100 oscillations.	Proportional Intensity.
h m			h m		
A.M. 0 52	291.9	1173	A.M. 0 51	620.5	2597
1 49	291.8	1174	1 46	620.0	2601
2 48	291.8	1174	2 48	620.0	2601
3 44	291.7	1175	3 44	620.6	2596
4 46	292.1	1172	4 45	619.8	2603
5 48	292.2	1171	5 46	619.3	2607
6 47	292.2	1171	6 46	620.4	2598
7 40	292.7	1167	7 41	620.6	2596
9 16	292.6	1168	9 22	618.3	2616
10 00	292.9	1166	10 2	618.0	2618
10 52	292.8	1167	10 54	617.1	2626
11 47	293.0	1165	11 49	615.9	2636
P.M. 0 47	293.1	1164	P.M. 0 46	615.9	2636
1 50	293.1	1164	1 48	616.8	2629
2 47	293.4	1161	2 47	618.9	2611
3 40	293.3	1162	3 41	618.9	2611
5 43	292.3	1171	5 47	617.8	2620
6 43	293.0	1165	6 44	618.8	2612
8 7	292.4	1170	8 7	618.9	2611
8 53	292.5	1169	8 52	618.8	2612
9 51	292.1	1172	9 52	618.2	2617
10 49	292.2	1171	10 52	618.8	2612
11 47	292.0	1173	11 48	619.3	2607

On looking over this Table it will be seen, that when an increased intensity obtained in the dipping needle, a corresponding diminution generally exhibited itself in the horizontal needle, and vice versa. But to compare this Table with the results deduced from my former experiments, and with the hypothesis of a rotation of the general polarizing axis of the earth about its mean position

as a centre, it will be best to express the intensities in terms of the magnetic latitude; viz.

$$* \mathrm{I} = \mathrm{A}\sqrt{3\,\text{sine}^2\lambda + 1} = \text{Intensity dipping needle,}$$

$$\mathrm{I} = \mathrm{A}\cos\lambda \qquad = \text{Intensity horizontal needle:}$$

where λ is the magnetic latitude. If we assume $81°$ as the mean dip at Treurenburgh Bay, and since

$$\text{Tang.}\,\delta = 2\,\text{tang.}\,\lambda,$$

or tang. $\lambda = \frac{1}{2}$ tang. $81°$, we have $\lambda = 72° \, 30'$ the mean magnetic latitude. Let x be the radius of the circle of rotation assumed in the hypothesis; then the extreme latitudes will be $72\frac{1}{2}° + x$ and $72\frac{1}{2}° - x$, and the intensities varying in their greatest extreme, as 2596 to 2636; we have to find x such, that

$$\text{Cos}\,(72\tfrac{1}{2}° + x) : \cos\,(72\tfrac{1}{2}° - x) : 2596 : 2636.$$

This gives $x = 8$ minutes very nearly; whereas in my former paper I suppose this radius not to exceed $2\frac{1}{2}$ minutes. In that case, however, the deduction was made from the mean results of several months' observations, commencing with January, when the effect is the least; whereas this is drawn from the extreme results of eleven days only, and at that season when the effects are the greatest.

Assuming the above radius of rotation, viz. 8 minutes, it is easily ascertained that the corresponding maximum change in the daily variation ought to be 54 minutes; whereas it appears by the Table published in the Appendix to Captain PARRY's Narrative of his Attempt to reach the North Pole of the Earth, to have amounted to $1° \, 32'$ from the mean of eleven days' observations.

The $2\frac{1}{2}$ minutes assumed as the radius of rotation of the magnetic pole, from the mean of the Port Bowen experiments, is certainly too small to answer even to the mean results: but if we take the mean results as there obtained for the month of May, which was the greatest observed, it will be found that the radius of rotation would require to be taken at 8 minutes, the very quantity above determined. It will, however, be seen by referring to the paper in which the former experiments and observations are recorded, that the $2\frac{1}{2}$ minutes assumed for the radius was stated as a quantity altogether conjectural, no attempt being made to establish it by calculation. At all events it will be

* Barlow's Essay on Magnetic Attractions, page 197, 2nd edition.

necessary to consider this radius as changing very considerably as the sun advances to the north.

The change of intensity in the dipping needle as depending on the change of dip or of the magnetic latitude, would be only as 3726 to 3732, whereas it is found to amount to $\frac{1}{83}$rd part of the whole. This therefore seems to indicate a change in the general co-efficient A, and that this is greatest when the dip is greatest, and least when the dip is least.

We might be able to separate these two counteracting effects on the horizontal needle; but it would probably be considered too speculative in the present stage of this inquiry. All therefore that I shall consider as demonstrated by these experiments is, that the cause of the daily change in the horizontal intensity is principally due to a change of dip, as I found to be the case at Port Bowen, and that the times of the day when these changes are the greatest and least, point clearly to the sun as the primary agent in the production of them; and that this agency is such as to produce a constant inflection of the pole towards the sun during the twenty-four hours: this is, I think, clearly established as far as comparison has yet been made, and I hope soon to be able to submit this inquiry to the test of experiments under circumstances so different in every respect from these and the former, that they cannot fail of either confirming or contradicting the hypothesis in question.

London,
March 4th, 1828.

HENRY FOSTER.